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Thermal Effects on Some Mangrove Mollusks

by

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Abstract. The thermal tolerance to temperature of five species of tropical intertidal mollusks—*Coecella horsfieldi horsfieldi, Diplodonta cumingii, Melongena pugilina, Mytilus viridis,* and *Terebralia sulcata*—were studied. Heat coma, acute lethal temperatures, and 6-h median tolerance limits were used as measures of thermal tolerance. Each of these three indices produced a correlation between intertidal location and the sensitivity of the species to thermal stress.

INTRODUCTION

THE USE OF COASTAL waters for cooling in electricity generating plants is increasing with greater demands for power. A number of these power plants are located near estuaries and utilize estuarine water for cooling and discharging heated water at temperatures about 10 to 15 C° above ambient. Although at the moment thermal pollution is not critical, it is anticipated that in time to come, with more powerful conventional as well as nuclear power plants being built, thermal discharges could create problems to coastal ecosystems (NAYLOR, 1965).

In the tropics and in the South-east Asian countries where inland water resources are limited, many of these plants will be located on the coast and near mangroves. Thermal changes in the mangrove environment could also result from other sources, such as land development for agriculture and industries, which could change the temperature regime of surrounding waters.

Most studies on thermal effects have been conducted in temperate regions (NAYLOR, 1965; HEDGPETH & GONOR, 1969). One of the few conducted in the tropical region of South-east Asia was a study by MENASVETA (1976), who evaluated the thermal effects on marine fishes of the Gulf of Thailand.

Knowledge of thermal effects on the tropical mangrove ecosystem and the associated organisms is very limited. Our study contributes to this knowledge by investigating the effects of heated water on five intertidal mollusks found in the local mangrove mudflats of Singapore. The thermal tolerance to increased temperature of the bivalves *Coecella horsfieldi horsfieldi* (Gray), *Diplodonta cumingii* Hanley, and *Mytilus viridis* L., as well as the gastropods *Melongena pugilina* (Born) and *Terebralia sulcata* (Born), were investigated. Hereafter, these species will be indicated by their generic names.

MATERIALS AND METHODS

For each species, 12 batches of 10 individuals were placed in 400-ml glass beakers containing well aerated seawater (30 ppt) and placed in a thermostated water-bath that was maintained at the test temperature. At hourly intervals a batch of 10 was randomly selected, and the number that survived was noted. Mortality was determined by placing the treated animals back into seawater maintained at room temperature (25°C) and then testing for sensitivity responses of the foot or valve when the foot of the animal was pricked with a needle (SOUTHWARD, 1958). Animals that did not respond were considered dead.

The sensitivity test with the needle was also conducted on the animals 5 min after treatment. The heat coma point was defined as the lowest temperature at which no response was elicited initially from the animal but on returning the animal to room temperature full activity was regained.

Treatment temperatures used in the experiments ranged from 25 to 52.5°C at 2–3 C° intervals. These treatment temperatures for each species are given in Table 1. The animals were acclimated to room temperature (25°C) for 24 h before they were used in the experiments.

The survival curves for each species and at each treatment temperature were obtained by plotting the number alive against duration of treatment (Figure 1). After transforming these curves into linear form by plotting the probit of survival against the logarithm of treatment duration, the 50% survival times were extracted and a sensitivity curve for each species was drawn by plotting 50% survival time against treatment temperature (Figure 2). From this, the acute lethal temperature (ALT) was obtained. This is the temperature at which 50% of the animals will die instantaneously.

Another thermal tolerance index was determined from

Table 1

Treatment temperatures of five mangrove mollusks.

Species	Treatment temperatures °C								
Coecella horsfieldi horsfieldi	25	38	40.5	45	46	47.5	50	52.5	
Diplodonta cumingii	25	33	35	40	41.5	43	45	47	
Terebralia sulcata	25	38	40	43	45	47	49	51	
Melongena pugilina	25	35	38.5	39.5	40.5	41.5	42.5	45	47
Mytilus viridis	25	35	37.5	38.5	39.5	41	43	45	

the 6-h temperature-mortality curves ($_{6\text{-h}}TL_m$). The 6-h limit was chosen because most of these intertidal animals are seldom submerged for more than 6 h per tidal cycle in the natural environment.

RESULTS

Habitat of Test Organisms

Coecella, Diplodonta, and *Terebralia* are normally found in the upper intertidal zone of the mangroves, whereas *Melongena* and *Mytilus* are lower intertidal species.

Coecella is buried near the surface in sandbars located in the tributaries draining the mangrove swamp. *Diplodonta* is buried deeper in compact, moist mud, usually located between the roots of the mangrove plants, and this species is often found together with the peanut worm *Phascolosoma lurco* (Selenka & de Man). *Terebralia* is found along the muddy banks at the base of the mangrove plants among the pneumatophores.

Melongena frequents moist, muddy habitats and areas with large gravel and stones. *Mytilus* is found attached to solid substrata, such as poles or concrete pillars, farther away from the mangrove trees.

These intertidal mollusks are usually subjected to semidiurnal tides and are submerged and exposed twice a day. The upper intertidal species are subjected to a longer duration of desiccation and solar radiation than the lower intertidal species. All are also subjected to fluctuating salinities which ranged between 25 and 30 ppt, the former at low tides and the latter at high tides.

Behavioral Responses to Heated Water

In general, all five species showed four phases of response when exposed to increasing degrees of heated water. At the lower temperature levels, the animals were active and responded readily to needle pricks. *Coecella* and *Diplodonta* showed vigorous burrowing movements of their muscular foot. Specimens of *Mytilus* produced byssus for attachment to the beaker and constantly opened and closed their valves. Active crawling was observed in *Melongena* and *Terebralia*. When pricked by a needle, both the bivalves and the gastropods showed their sensitivity by immediate withdrawal of the foot or closure of the valves.

Following this initial stage, a phase of lethargy was observed. Occasional movements were noted and the animals reacted slowly to needle pricks while still submerged in the heated water. Copious secretion of mucus was observed. After this phase the animals showed no reaction when pricked. This occurred at higher temperatures, and the animals apparently were in a state of heat coma. These animals, however, regained their sensitivity to needle pricks when they were transferred to room temperature seawater.

At the fourth and final phase, the animals were completely insensitive to needle pricks even after they were transferred into room temperature water. The tissues of these dead animals were tough and hard, whereas in the previous comatose phase, the tissues were soft, flaccid, and discolored.

Survival and Sensitivity to Heated Water

The survival curves for the five species are given in Figure 1. The usual sigmoid survival patterns were observed. The resulting sensitivity curves (Figure 2) showed linear relationships between the 50% survival time and the treatment temperature for all five species. *Coecella* showed a slight deviation from the linear pattern.

Coecella and *Terebralia* had the highest thermal tolerance followed by *Melongena* and *Diplodonta*. The least tolerant was *Mytilus*.

The acute lethal temperature points (ALT), the temperatures at which 50% of the test animals would die instantaneously, were obtained from the sensitivity curves (Table 2). The ALT were highest, and similar, for *Coecella* and *Terebralia,* about 50 and 49°C respectively. These species were closely followed by *Melongena* and *Diplodonta* with ALT of about 45°C. *Mytilus* had the lowest ALT, about 43°C.

The heat coma temperatures (HCT) for the five species are also given in Table 2. The highest HCT was observed for *Coecella* (40.5°C) followed by *Terebralia* (40.0°C) and *Diplodonta* (35°C). *Melongena* and *Mytilus* had the lowest HCT (32°C).

The order of thermal tolerance measured by the HCT is similar to that indicated by the ALT. A temperature

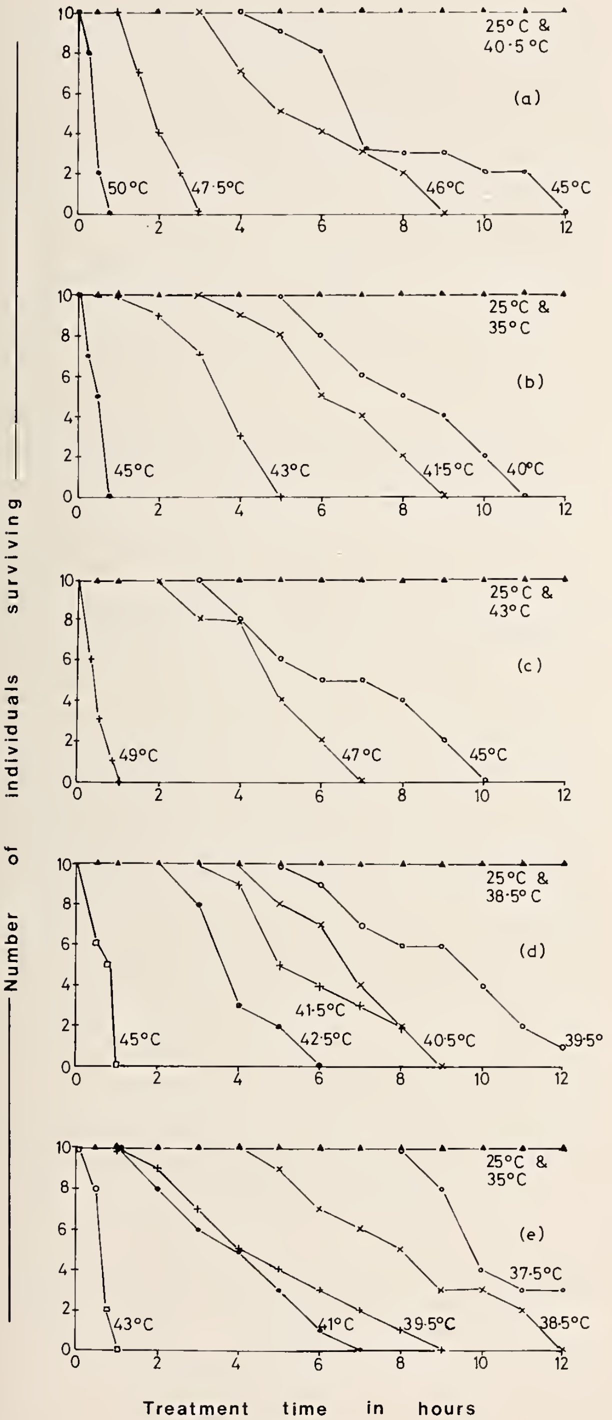

Figure 1

Survival curves of five species of mangrove mollusks subjected to different water temperatures. (a) *Coecella horsfieldi horsfieldi,* (b) *Diplodonta cumingii,* (c) *Terebralia sulcata,* (d) *Melongena pugilina,* (e) *Mytilus viridis.*

Table 2

Thermal tolerance values of five mangrove species of mollusks.

	Heat tolerance indices (°C)		
Species	Heat coma point	${}_{6\text{-h}}TL_m$	Acute lethal point
Coecella horsfieldi horsfieldi	40.5	45.8	49.7
Terebralia sulcata	40.0	44.9	49.4
Diplodonta cumingii	35.0	41.5	45.1
Melongena pugilina	32.0	41.2	45.4
Mytilus viridis	32.0	39.1	43.0

difference between the two indices of about 10 C° was observed for all five species.

The 6-h median tolerance limits, ${}_{6\text{-h}}TL_m$ (Table 2), extracted from the 6-h temperature-mortality curves (Figure 3), showed the same order of thermal tolerance as those obtained from the other two indices. However, their temperature values were halfway between the heat coma and the acute lethal temperature points. The temperature differences were almost the same for all species (4–5 C°).

DISCUSSION

Information on the temperature tolerance and response of intertidal marine animals is of importance in assessing the biological effects of thermal pollution and changed temperature regimes in the aquatic environment. Studies on a wide range of intertidal species are available (NAYLOR, 1965). However, benthic mollusks are especially suitable for assessing the ecological effects of any thermal stress, because, unlike the more mobile species such as fishes, they are unable to move away from the affected areas. Studies on mollusks are found in EVANS (1947, 1948), DAVIS (1960), SANDISON (1967), MISCALLEF & BANNISTER (1967), HEDGPETH & GONOR (1969), and ANSELL (1973). Studies on tropical species have been conducted by LEWIS (1960, 1963, 1971) and ANSELL & TREVALLION (1969).

In many countries, changes of temperature in the mangrove environment could result not only from direct thermal discharges of electricity generating stations but also from industrial heat waste, dams, irrigation practices, and other land use activities such as housing and industrial development nearby. In order to evaluate these changes and their potential effects on the mangrove ecosystem, the temperature tolerances of the resident organisms need to be investigated first.

Our results showed that the tolerance of high temperature by the five mollusk species is related to their vertical distribution along the shore. All three heat-tolerance indices indicate that the upper intertidal species, *Coecella* and *Terebralia,* were more tolerant than the lower inter-

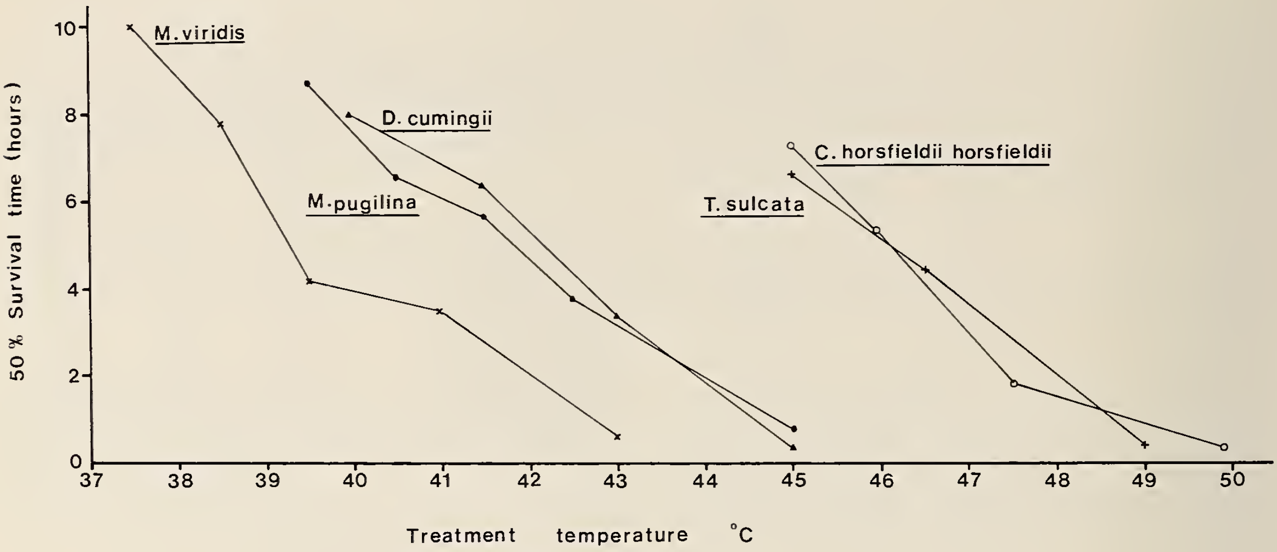

Figure 2

Temperature sensitivity curves of five species of mangrove mollusks. The 50% survival times (hours) were obtained from log-probit transformation of the survival curves.

tidal species, such as *Melongena* and *Mytilus*. *Diplodonta* is an exception: although it inhabits the upper intertidal, it has lower heat tolerance than the above two upper intertidal species. This is probably due to the fact that they are adapted to live deeper in the mud substratum where temperatures are normally lower than on the surface. A similar correlation with vertical zonation has been shown by other investigators (EVANS, 1948; BULLOCK, 1955; GUNTER, 1957; SOUTHWARD, 1958; SANDISON, 1967). They also have shown that thermal death points were correlated with the order in which animals were zoned on the shore.

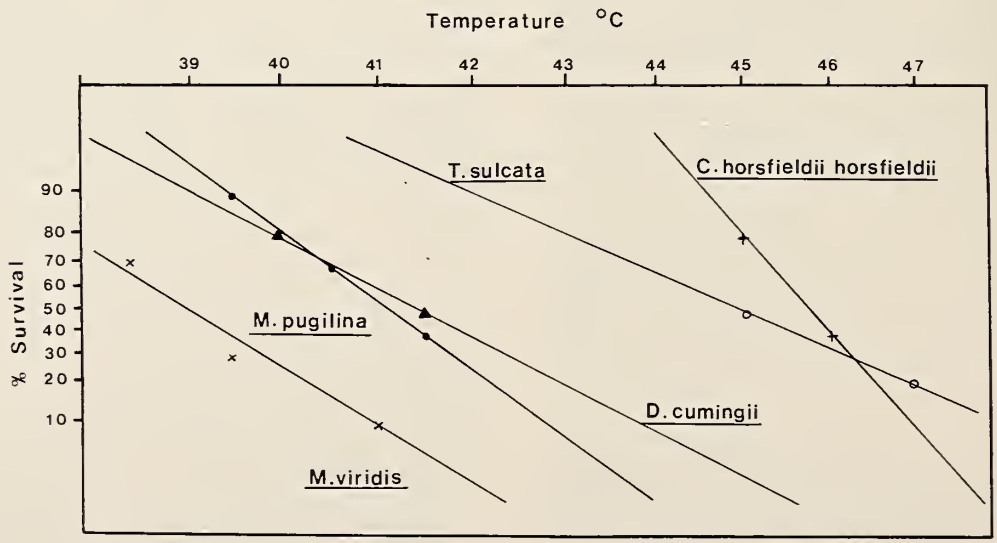

Figure 3

Six-hour temperature-survival curves of five species of mangrove mollusks. % survival on probit scale.

Of the five species investigated, *Mytilus* consistently showed the lowest heat-tolerance temperature indices. Therefore, it should be the indicator species for evaluating any thermal change, and their heat-tolerance temperatures used as a basis for thermal pollution control of the mangrove ecosystem.

The three heat-tolerance indices used in this study were the heat coma temperature (HCT) following SOUTHWARD (1958), the 6-h median tolerance limit ($_{6\text{-h}}TL_m$) using the usual bioassay methods, and the acute lethal temperature (ALT) derived from the sensitivity curves. If comparison of relative thermal tolerance among the species is required, it can be seen that any of the three indices could be used.

Based on the above, then 31-32°C should be the water temperature criterion for the protection of the mangrove ecosystem, and the decline in population size of *Mytilus,* or its disappearance, should be one of the indications of thermal stress to the ecosystem.

The temperature of the natural environment is between 28.5 and 30.5°C (THAM *et al.,* 1970). Therefore, the thermal stress temperature points of the species studied were very close to the ambient temperature of their natural environment. These tropical mangrove mollusks are living very near to conditions of thermal stress. A small increase of 2–3 C° in water temperature would be detrimental to them and the mangrove ecosystem. Here, as well as elsewhere, it seems that tropical organisms have low ranges of temperature tolerance (MOORE, 1972).

In conclusion, it can be seen that in terms of thermal stress, the mangrove is a fragile ecosystem. A slight temperature increase definitely would affect it. In developing the mangroves for aquaculture, agriculture, industrial or other land use, careful consideration, therefore, should be given to the changes in temperature regimes of the adjacent waters.

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